Appendix D: Protocol Development Summaries

Contents

This appendix presents a Protocol Development Summary (PDS) for each of the 12 monitoring protocols scheduled for development by the Northern Great Plains Network over the next 5 years. The PDS is a short document that identifies the Vital Sign(s) addressed by the protocol, describes why the protocol and monitoring is needed, specifies the monitoring objectives, and summarizes proposed methodological approaches and details about the protocol-development process.

The development of PDSs is an iterative process, requiring extensive input and feedback from park staff and cooperators to develop a succinct summary and realistic set of protocol development plans. These summaries will be updated as necessary to reflect the latest decisions on objectives, target populations, methods, cooperators, and other pertinent information.

Protocol Development Summary: Air Quality (14 April 2009)

Protocol: Air Quality [Air Quality]

Parks Where Protocol will be Implemented: BADL, THRO, WICA; TBD (AGFO, SCBL, DETO, NIOB)

Vital Signs Addressed by Protocol: 1) Ozone; 2) Wet and Dry Deposition; 3) Visibility and Particulate Matter; 4) Air Contaminants

Justification/Issues Being Addressed:
Ozone damage, nitrogen fertilization, and mercury inputs may be important stressors of terrestrial and aquatic communities (e.g., Miller 1973). Continued energy developments in Wyoming and North Dakota may increase pollution. Among NGPN units, active monitoring occurs only at the three Class 1 air quality parks. The regional network of stations may not cover some parks adequately. Monitoring with I&M funds may be implemented at AGFO, DETO, NIOB, and/or SCBL depending on results of work during 2008–2010 assessing potential gaps in current monitoring.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

1. Collect hourly, daily, or weekly measurements of ozone, wet/dry deposition (N compounds, mercury, and sulfur oxides), visibility, and particulates at BADL, THRO, and WICA.
2. Supplement NPS Air Resources Division (ARD) and regional monitoring by collecting hourly, daily, or weekly measurements of ozone amounts, nitrogen deposition, and/or mercury deposition at other selected NGPN parks.
3. At the spatial scale of individual parks, sub-regions (e.g., Black Hills), and entire Network, collaborate with ARD to report seasonal and annual descriptive statistics and to determine temporal variability and long-term trends of selected stressors that have the potential to cause large changes in vegetation composition and structure (ozone or nitrogen deposition) or to contaminate aquatic systems (mercury).

Basic Approach:
For air quality Vital Signs, most data will come from existing monitoring by ARD and states in BADL, THRO, and WICA, and from interpolations / model-based inference from the regional network of stations. Pohlman and Maniero (2005) summarized current monitoring efforts in the region, and provided initial recommendations for additional monitoring. The NGPN I&M staff continue to update this summary through discussions with parks and state agencies about current monitoring. The Network will work with ARD to specify procedures for annual data access, analysis, and reporting of these data.

Any additional long-term air monitoring would focus on major gaps in current monitoring for pollutants that pose the largest risk of causing major changes to our ecosystems. Such monitoring would be implemented collaboratively by ARD, the NGPN, and partners. Evaluation of current monitoring gaps for nitrogen deposition, ozone levels, and other parameters will involve comparison of model-based interpolative estimates of air quality attributes at selected parks with

on-the-ground monitoring of a selected index site in AGFO, NIOB, DETO, and other parks. Because of limited monitoring for mercury in the region, assessment of current monitoring gaps will be based on assessment of bulk mercury deposition in selected NGPN parks to determine if there are hotspots of high deposition. Additional discussions will be held with ARD to discuss whether assessment of within-park spatial variation in ozone levels and other pollutants is needed for THRO and/or BADL.

Principal Investigators and NPS Lead:
The NPS Air Resources Division will take the lead on all aspects of data collection, including ongoing monitoring and most data collection and analyses during examination of the need for additional monitoring. Primary ARD lead contacts are John Ray, Ellen Porter, and Kristi Morris. Dr. James Stone, South Dakota School of Mines and Technology, is the lead on the 2008–2010 assessment of bulk mercury deposition. The NPS I&M contact currently is Kara Paintner at NGPN, 605-341-2807.

Development Schedule, Budget, and Expected Interim Products:
During 2008–2009, the NGPN will work with ARD to discuss protocol development, particularly to assess to what extent the monitoring objectives are already covered by existing ARD analysis and reporting procedures. In 2008–2010, the NGPN will be working with ARD to assess current gaps in monitoring of ozone and N-deposition, and mercury (through additional collaboration with Dr. James Stone). In addition to assessing adequacy of current monitoring for estimating changes at each NGPN park, the Network, ARD, Dr. Amy Symstad (USGS-BRD), and USGS South Dakota Water Sciences Center will further discuss the sensitivity of NGPN ecosystems to these contaminants and implement some research to establish critical loads for nitrogen or other pollutants. A draft protocol for reporting and analysis will be ready by Nov 2011 and implemented in 2012. The NGPN has budgeted $40,000 for assessment of current monitoring in 2008, $20,000 in 2009, and $20,000 in 2010.

Protocol Development Summary: Weather and Climate (15 April 2009)

Protocol: Weather and Climate [Weather and Climate]

Parks Where Protocol will be Implemented: All NGPN parks

Vital Signs Addressed by Protocol: Weather and Climate

Justification/Issues Being Addressed:
This is a fundamental driver of NGPN ecosystems. Trends in temperature and precipitation need to be understood in order to explain trends in other resources; annual climate measures are needed as covariates in trend analysis for many Vital Signs due to high among-year variability. Existing efforts through several regional and national networks of weather / climate stations collect these data; the NPS national I&M program has provided a portal to access summaries and raw data. Davey et al. (2007) identified gaps in current weather/climate monitoring; the Network is discussing how to address these needs.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

1. Determine daily, monthly, seasonal, and annual descriptive summaries for average temperature, temperature extremes, total precipitation, temporal *x* amount-class distribution of precipitation events, and wind characteristics from at least one index station in or near each park unit.
2. Provide an internet portal by which parks can access summaries and raw data from these stations.
3. Determine patterns of among-year variability and long-term trends in these weather/climate variables.

Basic Approach:
This protocol will focus primarily on data retrieval and summarization for data from existing index stations operated in or near NGPN parks by NPS, the National Weather Service and NOAA, and other programs. Davey et al. (2007) provided a summary of current monitoring stations in the Network; an update of park-based stations is being prepared by the NGPN I&M staff. Over the next year, the Network will evaluate the adequacy of existing stations for providing data of suitable quality and sufficient proximity to each NGPN park. Potential gaps in current monitoring will be prioritized, and the Network will examine possibilities of working with other funding sources and other NPS or non-NPS collaborators to fill high priority gaps. The Network will work closely with the NPS NPClime effort (http://science.nature.nps.gov/im/inventory/climate/wrcc/index.cfm), which will provide an internet portal for accessing real-time weather data, historical climate patterns, and station metadata for all NPS parks.

Many NGPN parks are small enough such that within-park variation in weather is likely to be minor. Data from one station or interpolated from multiple stations likely will be adequate for capturing temperature and precipitation patterns in these parks. At larger parks, particularly THRO and BADL, further evaluation of the adequacy of existing station coverage is needed. Analysis of spatial correlation among stations in these areas will be used to examine the

likelihood of high spatial *x* temporal heterogeneity within these larger parks. Model-based estimates of weather / climate attributes across each large park, based on data form index sites, will be investigated. This evaluation will be performed after further development of more detailed objectives and planned uses of the monitoring data to help determine what degree of spatial resolution and accuracy is needed. If further discussions with park staff and leads on other NGPN protocols indicate that we need more accurate estimates of temperature and precipitation in some areas of the larger parks, additional model development may occur. This may include periodic short-term deployment of supplementary data loggers to assess the accuracy of model-based interpolation and to refine the spatial model. NGPN will also take advantage of existing protocols by other I&M Networks, and will continue to discuss additional higher-order objectives for this Vital Sign (e.g., summarization of indices of drought or large-scale atmospheric regime states), and more specific monitoring questions and procedures for addressing these questions.

Principal Investigators and NPS Lead:
The lead on the National I&M Program's NPClime internet portal is John Gross. The NPS I&M lead currently is Kara Paintner at NGPN, 605-341-2807.

Development Schedule, Budget, and Expected Interim Products:
During 2009, the NGPN will consult with other networks and national I&M staff to refine monitoring objectives and summarize procedures for accessing, summarizing, and reporting data from existing stations. The need for additional examination of spatial models interpolating among existing stations will be examined. A draft protocol will be developed by June 2011, and full implementation is planned for June 2012. We will budget $10,000 in FY2009 and FY2010 for protocol development.

Protocol Development Summary: Stream and River Channel Characteristics (20 April 2009)

Protocol: Stream and River Channel Characteristics [Channel Characteristics]

Parks Where Protocol will be Implemented: All except JECA

Vital Signs Addressed by Protocol: Stream and River Channel Characteristics

Justification/Issues Being Addressed:
Changes in channel morphology affect sediment loads and alter riparian habitats (Gordon et al. 1992). Increased channelization contributes to reduction in active floodplains, reducing or eliminating recruitment of cottonwoods. Reduction in active sediment movements causes loss of nesting habitat for piping plovers and least terns, and reduction in suitable habitat for pallid sturgeons. Coarse changes in river channel characteristics can be measured inexpensively through aerial imagery. At Knife River Indian Villages and Fort Union Trading Post National Historic Sites, river erosion threatens archeological sites; park-led monitoring addresses this issue.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

1. In all parks except JECA and FOUS, determine status and long-term trends in channel profile, substrate composition, and bank characteristics at selected locations in perennial streams/rivers at 5–10-year intervals.
2. Through aerial imagery, examine changes in location and characteristics (sinuosity, width) of active river channels at 10-year intervals.
3. At KNRI and FOUS, determine rates of bank erosion in high concern archeological areas.
4. Correlate and compare changes in channel characteristics with changes in stream/river hydrology, floodplain and watershed land cover, and broader scale changes in channel locations.

Basic Approach:
This protocol is in early stages of development. At parks other than MNRR, sampling design and the extent of monitoring related to Objective 1 will be determined when sampling for aquatic macroinvertebrates and water quality. Baseline data for Objective 1 was collected by Dr. Nels Troelstrup and Jill Rust, and reported in Rust (2006). The protocol they recommended was an adaptation of the Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP). The Network will discuss this protocol further during 2010 with parks and USGS South Dakota Water Science Center. Methodology related to Objective 2 will be developed during the next 2–3 years. At most parks, we will rely on remote imagery used in the Landscape Pattern and Dynamics protocol.

At Missouri NRR, the Army Corps of Engineers (COE) currently collects QuickBird imagery of the river channel and measures channel profiles annually. These efforts are much more intensive than what the NGPN will implement at other Network parks. If this COE monitoring is to continue long term, the NGPN will collaborate with COE to discuss possibilities for data sharing and collaborative reporting related to Objectives 1-2.

At KNRI and FOUS, the parks currently have small-scale erosion monitoring of selected river-bank locations. At KNRI, the focus is on bank erosion near an important archeological site. At FOUS, the focus is on erosion of a small tract of park land across the Missouri River from the main park. Bank erosion is reducing the park landbase and eliminating large cottonwoods. At both parks, distance from the bank edge to fixed locations is measured annually. The NGPN will assess whether the I&M core staff should help summarize, report, and archive these data (Objective 3). For Objective 4, we have not begun assessing strategies for integrating data related to Objectives 1-3 with information from other protocols.

Principal Investigators and NPS Lead:
Dr. Nels Troelstrup, of South Dakota State University, collected baseline data related to Objective 1. Dr. Joyce Williamson of the USGS South Dakota Water Science Center will provide recommendations regarding methods for Objective 1. The NPS I&M lead is Joel Brumm at NGPN, 605-341-2804.

Development Schedule, Budget, and Expected Interim Products:
Methodology related to Objective 1 will be developed simultaneously with protocol development for Water Quality. Additional significant protocol development efforts may not occur until 2010, other than continued discussions with MNRR about COE data. A draft protocol will be completed by the end of 2012, with full implementation in 2014.

Protocol Development Summary: Cave Water and Meteorology (7 April 2009)

Protocol: Cave Water and Meteorology [Cave Water and Climate]

Parks Where Protocol will be Implemented: JECA and WICA

Vital Signs Addressed by Protocol: 1) Cave Meteorology; 2) Cave Water Chemistry; 3) Aquatic Contaminants; 4) Groundwater Dynamics

Justification/Issues Being Addressed:
Jewel Cave and Wind Cave are globally significant caves and are the reason for the establishment of their respective parks. Maintaining stable conditions in the caves is a fundamental mission of these parks. Toomey (2006) identified cave climate as the most important attribute to monitor in cave environments. Internal changes in humidity and temperature, resulting from external climate changes and visitor tours, could degrade delicate physical formations (e.g., gypsum strands) deep in the cave (Nepstad and Pisarowicz 1989). Climate change could also affect the large winter population of hibernating bats (Choate and Anderson 1997), and the detritus-based food web of the cave (Moore 1996; Nepstad and Pisarowicz 1989). Changes in airflow patterns, from modification of cave entrances or other management actions, could alter the cave environment. Monitoring cave water quality may allow detection of surface contamination from developed sites or aquifer pollution that would not be captured by surface water sampling. Wind Cave offers direct access to the Madison Aquifer, allowing detection of changes in water level caused by drought or withdrawals.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

1. Determine seasonal, annual, and long-term changes in the water level of the Madison Aquifer in Wind Cave.
2. Detect changes in selected water quality parameters and contaminants in the aquifer, drip sites and other water sources below developed areas and selected undeveloped areas of Jewel Cave and Wind Cave.
3. Determine trends in temperature (mean, variation) at selected sites near entrance and interior portions of Jewel Cave and Wind Cave.
4. Determine changes in entrance airflow characteristics (direction, speed, and temperature, which can be used for heat, air mass, and water mass exchange calculations) at natural entrances of Jewel Cave and Wind Cave.

Basic Approach:
In February 2008, NGPN I&M core staff and park cave experts from JECA and WICA held a 1-day meeting to summarize important characteristics of each cave and identify stressors of high concern. Candidate monitoring objectives were prioritized, and through subsequent discussions the Network agreed to focus on the 4 objectives listed above. Given that each park has been intermittently involved in various aspects of cave water and climate assessments over the past 4 to 5 decades, the purpose of this protocol is to enhance and standardize monitoring efforts by the two parks: Our expectation is to develop formal sampling and measurement approaches that will provide comparable data for deciphering long-term trends in cave attributes at both parks. JECA and WICA staff, or their affiliates, will continue to perform sampling in the cave, while I&M

will provide support, when and where possible, in the form of sampling design assistance, data management, statistical analyses, equipment acquisition, and funding for consultant fees or park staff salaries. It is expected that aquatic sampling will follow recognized practices (such as those recommended and employed by USGS hydrologists or the EPA) for periodically assessing water quality and quantity, while cave meteorology and airflow sampling will incorporate methods similar to those utilized by Mammoth Cave NP (MACA) and Dr. Andreas Pflitsch (Cave Climatologist, Ruhr University, Bochum, Germany), who has conducted such research at both parks.

Airflow characteristics will be monitored at the single natural entrance at Jewel Cave and at one or both natural entrances at Wind Cave. For interior climate and water quality measurements, we are unable to sample a cave-wide target population due to high travel time to most of the cave and due to potential damage to cave features caused by frequent travel. Internal climate monitoring will use automated temperature loggers placed at selected index sites on and off tour routes, close and far from natural entrances, and at bat hibernacula (in JECA). Because relative humidity is near-saturation, except near the cave entrances, sensor limitations prevent monitoring of air moisture deep in the cave interior. In Wind Cave, an automated logger will record water level continuously in cave lakes, where the Madison Aquifer is exposed. At selected accessible drip sites and streamlets at Jewel Cave and Wind Cave, water quality monitoring will measure water temperature and other core parameters when feasible. Water-sampling index locations will be selected in portions of the cave under developed and non-developed surface areas. As noted above, WICA and JECA cave staff will deploy equipment and retrieve data for all sampling efforts and related observations.

Principal Investigators and NPS Lead:
At this time, Mike Wiles (JECA Physical Science Specialist), Dr. Rickard S. Toomey III (University of Western Kentucky), Shane Fryer (LABE), and Johnathan Jernigan (MACA) are developing a national-level protocol for cave meteorology; while Cami Pulman (TICA), Ben Tolman (SEKI), John Roth (ORCA), Joe Meiman (CUPN/GULN), and Mark Ohms (WICA) are developing a national-level protocol for cave hydrology. At their completion, we intend to adapt these protocols to fit the needs of JECA and WICA, while continuing to collaborate and consult with Dr. Andreas Pflitsch and the USGS South Dakota Water Science Center. Rod Horrocks (WICA Physical Science Specialist) and Mile Wiles (JECA Physical Science Specialist) will represent their respective parks in this effort. The NPS I&M lead is Mike Bynum at NGPN, 605-341-2801.

Development Schedule, Budget, and Expected Interim Products:
Following the guidelines of the national-level protocols, sampling and measurement approaches will be refined in 2010. We are anticipating that a cave water and meteorology protocol will be ready for external peer review by Dec 2010. After peer review, revision and approval, we plan to implement the protocol in Dec 2011. We will budget $10,000 in FY2010 and FY2011 for protocol development, and equipment acquisition where necessary.

Protocol Development Summary: Surface and Groundwater Hydrology (20 April 2009)

Protocol: Surface and Groundwater Hydrology [Hydrology]

Parks Where Protocol will be Implemented: All NGPN parks [AGFO, BADL, DETO, FOLA, FOUS, JECA, KNRI, MNRR, MORU, NIOB, SCBL, THRO, WICA]

Vital Signs Addressed by Protocol: 1) Surface Water Dynamics; 2) Groundwater Dynamics

Justification/Issues Being Addressed:
Throughout most of the Northern Great Plains, water is a limited and important resource. Dams, irrigation and municipal withdrawals, and groundwater depletion have significantly changed the hydrographs of most NGPN rivers, with large-scale effects on aquatic and riparian ecosystem (Longo and Yoskowitz 2002). Thus, water quantity as well as water quality is a critical component of aquatic ecosystem condition, and parks need to track patterns of stream and river flow/discharge. In addition, NPS WRD considers flow/discharge a core parameter that must be assessed, quantitatively or qualitatively, when water quality measurements are collected. In portions of the Network (southern Black Hills, Nebraska, and Wyoming), groundwater sources are increasingly endangered because ground water is being withdrawn from aquifers faster than it is being recharged (Flores 1995). Luckey et al. (1988) reported groundwater declines of 50–100 feet in the vicinity of Network parks in western Nebraska – potentially impairing the "free-flowing conditions" of the Niobrara National Scenic River. Similarly, a private entity has proposed a rural water system adjacent to WICA that could cause significant declines in groundwater levels in the park/cave within just one year of continuous pumping. By summarizing and reporting data from USGS stream gages, park-specific well-level monitoring at some parks, and regional monitoring of groundwater levels by Natural Resource Districts and other entities, the Network can help examine changes in river flow and detect impending threats to park groundwater sources.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

1. From active USGS flow gages in and near NGPN parks, summarize seasonal and annual trends and variation in discharge, stream/river water levels and peak annual flow.
2. At water quality sampling locations in selected NGPN streams and rivers, determine discharge at the time of sampling to help interpret water quality data and (for reaches without USGS gages) to examine seasonal and long-term trends in discharge.
3. At existing wells in selected NGPN parks determine seasonal and annual variations and long-term trends in hydrographs for groundwater levels.
4. Obtain aquifer-level monitoring summaries from other state and regional groundwater monitoring networks to examine impending threats to park groundwater supplies.
5. Determine correlations between trends in stream flows and groundwater dynamics vs. changes in weather/climate, park and watershed landcover changes, and other human activities and developments.

Basic Approach:
Most objectives will be met by accessing data collected by USGS, states, and regional entities (e.g., Nebraska Natural Resource Districts). Summaries of existing monitoring and procedures for obtaining, summarizing, and reporting data from these locations are being developed. For flow/discharge data collected by I&M personnel, the sampling design will be determined mostly by the sampling design for the Water Quality protocol, to be developed over the next eighteen months. Below, we describe our general planned approach.

Where possible or practical, quantitative flow measurements will be collected at or near the water quality monitoring sites of selected streams or rivers (see Water Quality protocol). Discharge will be measured using accepted techniques (flow trackers or current meter), with specific regard for the characteristics of each site. For monitoring sites near a USGS or state stream flow gage, the gage height will be noted at the time of sampling and the corresponding discharge will be requested from the agency. Discharge measurements will help with interpretation and comparisons of water quality data as well as with calculation of parameter load. Methods for statistical analysis for these data and all other hydrology data, and for synthesizing data with results from other protocols, will be determined.

In addition to obtaining gage data at the time of water quality measurements, the Network will access year-round (or spring-autumn ice-free season) data from gages in NGPN parks and from the closest gages upstream and downstream on streams / rivers passing through these parks. We will collaborate with USGS and states to obtain, summarize, and determine status and trends in the data. The Network will report basic summaries of these data annually to parks, and facilitate internet access by parks to raw data from USGS and states.

Parks such as WICA are currently using water level data loggers in wells to determine fluctuations within the aquifer. For regional groundwater monitoring, the Network will obtain monitoring summaries from state or other regional groundwater monitoring networks to examine impending threats to park groundwater supplies. Procedures for accessing and summarizing these data will be developed.

Principal Investigators and NPS Lead:
Dr. Joyce Williamson, of the USGS South Dakota Water Science Center, will be the P.I. for the final protocol development. The NPS contact person is Marcia Wilson at NGPN, 605-341-2803.

Development Schedule, Budget, and Expected Interim Products:
In June 2008, an interagency agreement was signed between NPS and USGS to identify current water resource sampling efforts in and around the NGPN park units. By the end of 2009, summaries of current gage and groundwater monitoring locations should be available. By July 2009, procedures for accessing data from these sites will be developed. A draft hydrology protocol will be ready for external peer review by October 2010. After peer review, revision and approval, we plan to implement the protocol in May 2011. We will budget $10,000 in FY2009 and FY2010 for protocol development.

Protocol Development Summary: Water Quality (20 April 2009)

Protocol: Water Quality of Streams, Rivers, and Springs [Water Quality]

Parks Where Protocol will be Implemented: AGFO, BADL, DETO, FOLA, JECA, KNRI, MNRR, MORU, NIOB, SCBL, THRO, and WICA

Vital Signs Addressed by Protocol: 1) Surface Water Chemistry; 2) Aquatic Contaminants; 3) Aquatic Microorganisms; 4) Aquatic Macroinvertebrates

Justification/Issues Being Addressed:
Given that pollution of water by point and nonpoint sources can cause severe deterioration of aquatic systems and diminish the visitor's experience, the NPS is committed to the protection, maintenance, or restoration of water resources within the parks consistent with the Clean Water Act and other applicable laws and regulations (NPS Management Policies 2006). Therefore, funding is granted to I&M Networks specifically for water quality monitoring. In addition, the NGPN identified water quality as a top monitoring priority early during the Vital Signs selection process. This monitoring is needed to assess NGPN ecological health, measure compliance with federal and state laws and standards, as well as detect threats to human health. All parks are concerned about changes in park aquatic resources due to dams, agricultural uses, and human developments in the surrounding watershed. For example, heavy livestock grazing and feedlots may increase erosion, turbidity, nutrient inputs, and bacterial levels (Scrimgeour and Kendall 2003). Herbicides from farmland may alter macroinvertebrate abundance and species composition (Lenat 1984). Roads and developments alter runoff, sedimentation, water chemistry, light, and temperature (Trombulak and Frissell 2000). The Network will focus water quality monitoring on four Vital Signs: Surface Water Chemistry, Aquatic Contaminants, Aquatic Microorganisms, and Aquatic Macroinvertebrates. Because sampling for these protocols will be conducted by the same field crew, and this sampling will be co-located, these Vital Signs are addressed by a single monitoring protocol.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

1. In all NGPN parks with surface water, determine status and trends in temperature, pH, dissolved oxygen, and specific conductivity at selected locations in perennial streams/rivers and springs.
2. At selected locations in NGPN perennial rivers and streams, determine status and trends in diversity, abundance, and community metrics of aquatic macroinvertebrates.
3. Determine status and trends in high-priority contaminants and aquatic microorganisms in selected rivers, streams, and springs of NGPN parks at intervals to be determined.
4. Determine correlations between trends in water quality parameters vs. changes in discharge, stream channel characteristics, weather/climate, human activities and developments, and watershed land cover.

Basic Approach:
Currently, our objectives, sampling design, and measurement methods are under development. We may need to reduce the scope of this protocol if the objectives above are not feasible with available funding. During 2008–2009, we will be working closely with USGS, park staff, and

other NPS aquatic and statistical experts to solidify our planned approach. Pending further development, our planned approach uses continuous multi-parameter probes and periodic non-automated sampling for macroinvertebrates and other parameters. At each selected aquatic system, one or more index site(s) will be established nonprobabilistically, primarily because the continuous monitoring equipment is expensive. At each index site, a continuous multi-parameter probe will be deployed to determine trends in the four core water column parameters and turbidity. The Network will follow the specified state criteria under the CWA protocols, if a regulatory driver is chosen.

Aquatic macroinvertebrates sampling methods, sampling intervals, and frequency of sampling are still to be determined. Previous inventory work conducted by Rust (2006) was based on an adaptation of EPA's Environmental Monitoring and Assessment Program. We will also take into consideration the methodology that the Heartland Network has been using at Agate Fossil Beds NM for the past several years (Peitz and Cribbs 2005, Bowles et al. 2008). Macroinvertebrate sampling sites will be co-located with water quality index sites.

If funding permits, additional study reaches will be selected based on probability sampling of the portion of the waterbody within the park. At these additional reaches, the four core parameters and turbidity will be measured during each sampling event using multi-parameter probes. In order to achieve more widespread monitoring coverage of the Network water bodies, we anticipate using multi-panel revisit designs, and will be examining potential revisit schedules over the next year.

Selection of high priority aquatic contaminants and aquatic microorganisms is still to be determined as well as sampling methods and sampling intervals. For these objectives, the Network will explore the possibility of sharing analytical costs with the representative states.

Principal Investigators and NPS Lead:
Dr. Nels Troelstrup, of South Dakota State University, completed baseline inventories and assessments of macroinvertebrate assemblages throughout the Network. He also drafted a water resources protocol focusing on regulatory compliance for the beneficial uses assigned by each state to selected water bodies in the Network park units. Building on this draft protocol, Dr. Joyce Williamson of the USGS South Dakota Water Science Center will be the P.I. for the final protocol development. The NPS I&M lead is Dr. Marcia Wilson at NGPN, 605-341-2803.

Development Schedule, Budget, and Expected Interim Products:
In June 2008, an interagency agreement was signed between NPS and USGS to provide an ecological characterization of the water resources in the Northern Great Plains region, and to identify current water resource sampling efforts in and around the NGPN park units. In late summer/early fall 2008, the NGPN staff collected continuous pilot water quality data at the three parks containing portions of the Niobrara River (AGFO, NIOB, and MNRR). In December 2008, USGS and the Network co-organized a 2-day workshop of USGS experts, NGPN I&M core staff, park staff, and other NPS and external aquatic experts. The purpose of this workshop was to prioritize monitoring strategies and water bodies within each park. Based on the results of the workshop and the 2008 Niobrara River pilot project, the Network and USGS will inventory water quality parameters with continuous multi-parameter probes at selected park sites from May

through October 2009. In addition, we have budgeted $70,000 in FY2009 for USGS to develop a draft water quality protocol. This draft protocol will be ready for external peer review by October 2010. After peer review, revision and approval, we plan to begin implementing the protocol in May 2011.

Protocol Development Summary: Exotic Plant Early Detection (7 April 2009)

Protocol: Exotic Plant Early Detection [Early Detection]

Parks Where Protocol will be Implemented: All NGPN parks [AGFO, BADL, DETO, FOLA, FOUS, JECA, KNRI, MNRR, MORU, NIOB, SCBL, THRO, WICA]

Vital Signs Addressed by Protocol: Exotic Plant Early Detection

Justification/Issues Being Addressed:
Controlling invasive plants is a high priority to NGPN parks (Symstad 2004) and a primary conservation issue globally (Mack et al. 2000), given the potential for the impairment of native ecosystems. Early detection and rapid treatment are the most effective way to control invaders (Hobbs and Humphries 1995; Rejmánek and Pitcairn 2002). The I&M program can help NPS prevent new establishments by helping parks and the Northern Great Plains Exotic Plant Management Team (EPMT) stay updated on high-risk non-established species, obtaining observations of these species from others on the ground, and conducting additional surveys.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

1. Develop and update every 1–5 yrs a list of, high-priority non-native plant species encroaching on each NGPN park unit.
2. Develop and distribute educational materials (e.g., identification and habitats of concern) about these species to parks, other NPS programs, partners and other agencies, and park visitors.
3. Develop and maintain a communications plan and online database for soliciting, storing, reporting, and sharing information about incidental observations of these species by park staff, other NPS program staff, partners, and visitors.
4. Based on qualitative or quantitative prioritization and prediction of habitats most at risk of colonization by targeted species, design and implement field sampling (in collaboration with park staff and volunteers) in each park at 2–5 year intervals to detect new occurrences of these species.

Basic Approach:
We have completed an inventory of the non-native plant species known to occur within the 13 parks of the NGPN, and a pilot list of invasive species that have been expanding their ranges toward this region. We are also exploring the possibility of using a Wyoming noxious weed database as a template for our online database. Discussions with EPMT have led to informal agreements to share data and information, such as GIS shapefiles and species occurrence records. However, integration of field surveys for new exotics between the two programs is not feasible because of EPMT's need to focus on treating acres and difficulties in having their personnel look for additional, and often unfamiliar, species during treatment sessions. We are in the initial stages of developing objectives related to field surveys and discussions to determine how to expand the Network's resources for exotic-plant searches through collaboration with park staff, partners, volunteers, and field personnel for other I&M protocols. Protocol development is on hold until fall 2009, when the lead on this Vital Sign returns from field work related to plot establishment for the Plant Communities Protocol.

Principal Investigators and NPS Lead:
The NPS I&M lead is Mike Bynum at NGPN, 605-341-2801.

Development Schedule, Budget, and Expected Interim Products:
In FY2009 and FY2010, we will complete priority species lists for the NGPN parks, using existing database resources; develop education materials, such as color brochures, PowerPoint presentations, and Web pages for informing park staff about the identification and ecological threats related to such species; and continue to explore objectives and methods related to field sampling for exotic plant species. We also intend to fund the development of an interactive Website for reporting and tracking the occurrences of these species on park units, with a projected completion date in FY2010, and produce a draft protocol by March 2011. The implementation of a specific sampling protocol for exotic species is still uncertain at this time, given the vast funding that would be required for this effort across the ~300,000 park acres that comprise the NGPN. We will budget $15,000 in FY2010 and FY2011 for the development of this protocol and its various components.

Protocol Development Summary: Plant Communities (1 April 2009)

Protocol: Upland and Riparian Lowland Vegetation Structure and Composition [Plant Communities]

Parks Where Protocol will be Implemented: All NGPN parks [AGFO, BADL, DETO, FOLA, FOUS, JECA, KNRI, MNRR, MORU, NIOB, SCBL, THRO, WICA]

Vital Signs Addressed by Protocol: 1) Riparian Lowland Plant Communities; 2) Upland Plant Communities; 3) Fire and Fuels Dynamics

Justification/Issues Being Addressed:
Monitoring of vegetation composition and structure was identified as a high priority throughout the NGPN. Vegetation composition and structure affect faunal abundance, distribution, and composition; influence local microclimate (e.g., Breshears and Barnes 1999), fire regimes (D'Antonio and Vitousek 1992), and nutrient flows into streams (Naiman et al. 2005); and are part of the scenery enjoyed by visitors. Plant community composition is sensitive to most stressors affecting NGPN parks, including external stressors such as exotic species, habitat fragmentation, river flow management, climate change, atmospheric nutrient deposition, pollution, and fire suppression, as well as management activities such as ungulate management, prescribed fire programs, visitor use, and exotic species control (Symstad 2004). Changes in cover, species occurrence, and structure at fine scales (e.g., increasing exotic species cover, lack of tree regeneration in riparian forests) may indicate or precede broader changes in the composition and productivity of park ecosystems. This protocol can be implemented cost effectively through collaboration with the Northern Great Plains Fire Ecology Program (FireEP). Monitoring of forest structure and dead and downed fuels in Black Hills parks will also help the NGPN and FireEP examine fire management effects and effectiveness and to shape future management actions.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

1. In all NGPN parks except MNRR and NIOB, determine park-wide status and long-term trends in vegetation species composition (e.g., non-native vs. native, forb vs. graminoid vs. shrub) and structure (e.g., cover, height) of herbaceous and shrub species.
2. Determine park-wide status (at 5-year intervals) and long-term trends of tree density by species, height class, and diameter class, and trends in forest fuel loads by fuels classes, in Black Hills parks (WICA, JECA, MORU, DETO).
3. Determine status (at 5-year intervals) and long-term trends of tree density by species, height class, and diameter class in lowland areas near perennial streams/rivers in selected parks (DETO, FOLA, KNRI, SCBL, THRO).
4. Determine trends in plant species composition and community structure in selected areas of NGPN large-river parks (MNRR and NIOB).
5. Improve our understanding of the effects of external drivers and management actions on plant species composition and vegetation structure by correlating changes in vegetation composition and structure with changes in climate, landscape patterns, atmospheric chemical composition, fire, and invasive plant control.

Basic Approach:
This protocol will meet combined monitoring objectives of the NGPN and FireEP. The protocol will be implemented using funding from both programs. The protocol will use three major sampling approaches. The first approach is intensive sampling, in which information on all the vascular vegetation at a site is collected. In this approach, the sampling unit will be a 20 x 50 m (0.1 ha) plot in which point-intercept and nested frame measurements will be used to capture vegetation height and species cover, frequency, and richness of herb-layer vegetation. In addition, standard forest measurements will capture structure (density by size class) and composition of trees and select tall shrub species. The second approach is extensive woody sampling, in which only the forest measurements are done in a smaller sampling unit (10-m radius circular plot; 0.31 ha). This approach will be used where tree density is a major management concern (Black Hills ponderosa pine forest and riparian forests in grassland parks), but its high variability requires larger sample sizes than could be accomplished with the intensive sampling. The third approach is yet to be determined, but will be tailored to monitor vegetation influenced by small, unconfined streams at AGFO and WICA.

At MNRR and NIOB, sampling methods will be determined after monitoring objectives are determined. For plant community monitoring at the other 11 NGPN parks, a preliminary protocol was proposed in January 2004 (Symstad 2004); field testing of methods was conducted in 2005; a draft protocol was finished in December 2006; and field work in 2008 was done to test refinements of the protocol for badlands sparse vegetation and to collect pilot data for forest structure monitoring in floodplain forests.

At all parks, sampling will focus on park-wide changes, with target populations that exclude areas near developments, roads, and steep areas that cannot be sampled safely. At DETO, FOLA, SCBL, and THRO, riparian/floodplain areas and upland areas will be placed in separate strata to facilitate unequal sampling intensity in the relatively small portion of each park in lowlands. At FOUS, the Bodmer Unit and the Fort Unit will be placed in separate strata to ensure adequate sample sizes in each of these distinct units. No stratification will be used at other parks.

At AGFO and SCBL, the Prairie Cluster Prototype Monitoring program has monitored plots in selected management areas, with data collected periodically over the last 10 years. These measurements have measured frequency in four subplot sizes cover in large (10 m^2) subplots via ocular estimates. Based on conversations with park staff, FireEP, and the Prairie Cluster (now Heartland I&M Network) staff, the NGPN I&M Program proposes to modify this legacy effort with the following strategy. 1) A subset of these legacy plots will continue to be monitored by the NGPN. At AGFO, the legacy plots will be those near the new interpretive trail to Carnegie Hill, allowing continuing evaluation of the effects of this construction activity and recovery of the vegetation from it. At SCBL, the legacy plots will be those in the golf course restoration and their associated controls in nearby prairie. 2) To allow the use of a single Network-wide protocol, we will transition measurements on these legacy plots from the existing protocol to the NGPN point-intercept and nested quadrat protocol. For two years, both methods will be used on these plots in hopes of calibrating the measurements so that past measurements based on the prototype protocol can be integrated with future NGPN measurements in analyses of long-term trends. 3) To ensure that these parks receive a high level of monitoring, we will implement

standard NGPN monitoring park-wide, with a larger plot number to park-area ratio than in many other parks in the NGPN. This will lead to a much higher sample size and greater spatial coverage than was feasible with prototype program alone.

To examine power and sample sizes for intensive vegetation monitoring, FireEP and Prairie Cluster Prototype data were analyzed with mixed-effects linear models to estimate variance components. This analysis indicated that systematic year-to-year variation was high and thus had an overriding effect on power to detect long-term trends. Quadrupling sample size yielded only small decreases in time to detect trend, and evaluation of several rotating and split-panel designs found minor differences in power to detect trend for a fixed annual sample size. In contrast, these analyses did suggest that greater sample size would increase the precision of status estimates of attributes with high spatial variation, such as proportion exotic cover. Given these results, we chose a [2-3] panel/revisit design for most parks for the intensive plots. For the largest parks (BADL and THRO), we increased the revisit interval to double the sample size, yielding a [2-8] revisit design. This design maintains an even workload for NGPN staff across years and provides reasonable sample sizes for domain analysis if desired. We anticipate 429 sites will be monitored across 11 parks.

Data from non-network studies/monitoring and network pilot sampling were used to estimate sample sizes needed for extensive woody sampling. Because the emphasis on this monitoring is to estimate status, and because interannual variability in forest structure is generally low, the revisit design for this sampling will be a [1-4] design, in which all extensive woody plots in a park are sampled in the same year and revisited every five years. With significant assistance from the NGP FireEP, we anticipate 435 extensive woody sites will be monitored across eight parks.

Apart from existing Prairie Cluster Prototype plots at AGFO and SCBL, all plots will be selected using a GRTS approach. The sample frame will be a 54 x 54 m grid covering all of each park, with inaccessible and developed areas excluded. The grid size is chosen to allow sufficient spacing between transects if two adjacent sample units were selected. In Black Hills parks, KNRI, and riparian/floodplain strata, the intensive vegetation plots will be a spatially balanced subsample nested within the larger number of plots selected for woody vegetation sampling. As a result, these two plot types will be partially co-located (i.e., at every sample location for intensive plots, we will also sample the woody-vegetation plot).

Principal Investigators and NPS Lead:
The principal investigator is Dr. Amy Symstad, a research ecologist with the USGS Northern Prairie Wildlife Research Center. Cody Wienk, the Midwest Regional fire ecologist, has collaborated closely with Amy and the NGPN to ensure that the protocol meets important needs of FireEP. The Network contact person is Mike Bynum at 605-341-2801.

Development Schedule, Budget, and Expected Interim Products:
The following tasks will be completed during 2009 to produce a complete protocol for peer review.

- In 2009, NGPN staff will sample the retained Prairie Cluster Prototype plots at AGFO and SCBL simultaneously with HTLN crews in order to calibrate the current prototype protocol with the combined NGPN / FireEP protocol being implemented Network-wide.
- Protocol development for MNRR and NIOB will include additional field visits and discussions with park staff to prioritize monitoring objectives for these large-river parks.

The current draft protocol applying to all parks except MNRR and NIOB will be revised and peer reviewed during 2009. For MNRR and NIOB, objectives and field methods will be finalized in fall 2009, if possible. Final approval will be sought by December 2009, with implementation in 2010. Approximately $20,000 will be allocated per year for protocol development during 2009. In addition, Dr. Amy Symstad's salary is covered by USGS. The I&M Program will hire a GS-11 Plant Ecologist in 2009 to help finish protocol development and lead implementation.

Protocol Development Summary: Land Birds (20 April 2009)

Protocol: Breeding Season Land Birds [Land Birds]

Parks Where Protocol will be Implemented: All NGPN parks [TBD]

Vital Signs Addressed by Protocol: Land Birds

Justification/Issues Being Addressed:
Land birds are of high interest to park managers; are a species-rich group that parks must conserve and protect; and can reflect changes in habitat structure, climate, food supply, nest predation, and landscape characteristics. In addition, NGPN parks can serve as reference sites for helping interpret regional trends in abundance for species of concern and other birds. Of the 100 landbird species in Canada and the U.S. on the Partners in Flight (PIF) Watch List (Riche et al. 2004), ~1/3 occur in NGPN parks. These species are included on the Watch List because of threats to their habitats, declining populations, small population sizes, or limited distributions. Over 1/2 of species on the 2004 PIF North American Land Conservation Plan Stewardship Species List are in NGPN parks.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

1. Determine changes in breeding-season density of common landbird species, relative abundance and occupancy of less common species, species richness, and other community characteristics in all NGPN parks or in selected habitat types (grasslands, floodplains, and/or Black Hills forests).
2. Determine correlations between avian population and community changes with changes in land cover, vegetation structural stages, landscape composition, and climate.
3. Determine similarity of these park-level trends vs. regional trends estimated by Breeding Bird Surveys and other monitoring efforts.

Basic Approach:
Although the NGPN currently plans to monitor land birds at all Network parks, our focus likely will be narrowed as we prioritize species groups for monitoring (e.g., forests vs. grassland assemblages) and determine what we can accomplish with available funding. For example, the final protocol may include intensive sampling at some parks and less intensive or less frequent sampling at other parks.

Established protocols for other NPS I&M Networks (e.g., Peitz 2007) and other monitoring efforts rely on standard variable circular-plot counts (variable-radius point counts) with distance estimation (Buckland et al. 2001) to derive density estimates. Our protocol will build on these well-developed procedures for monitoring landbird density. In particular, our protocol must tweak existing protocols to address four major methodological issues.

- Hybrid approaches integrating distance-sampling models with mark-recapture / removal-sampling models can help address unmet assumptions. For example, combining removal models with distance-sampling models can address violation of the assumption that detectability is 1.0 at the survey point, a necessary assumption when only distance sampling is used (e.g., Farnsworth et al. 2005).

- Analyses of species occurrence (occupancy) and community parameters (e.g., species richness) should account for incomplete detection of species during surveys (MacKenzie et al. 2006). Occupancy estimation can use data from standard point counts, but this requires careful choice of the spatial and temporal scale of sampling.
- In small NGPN parks of a few hundred hectares, population sizes of some species of interest, and the number of well-spaced sites available for sampling, may hinder our ability to precisely estimate density, occupancy, or trends (Panjabi 2005). Methods for dealing with these limitations need further consideration.
- Supplementing on-the-ground observer-based surveys with Automated Recording Units (ARUs) can help us assess accuracy of audio identifications made by field personnel and assess potential disturbance of some species by observers during point counts. Because observer surveys may entail only one or a few visits to each point during a year, ARUs provide a phenologic context for each year's survey, particularly in terms of capturing variation in arrival and breeding chronology that might affect point-count data for some species.

Given these issues, our sampling approach will utilize traditional variable circular-plot counts field methodology in a way that facilitates integrated analytical approaches for estimating density (i.e., distance sampling plus removal models) of wide spread species. We are examining the feasibility of a sampling design that also allows estimation of occupancy of less common species and overall community metrics so as to account for potential incomplete detection of some species. Finally, at one or more survey points in each park each year, we may deploy ARUs throughout the breeding season to capture temporal dynamics in arrival and calling behavior, and to doublecheck audio identifications recorded by on the ground observers. A protocol that integrates these approaches is being field-tested in 2008–2009 at Wind Cave NP.

At large and medium-sized NGPN parks, our sample unit likely will be a 3 x 3 or 4 x 4 grid of points, with 250-m spacing between grid points. Sample grids will be selected with a generalized random tessellation stratified (GRTS) approach (Stevens and Olsen 2004) to produce a probability sample with good spatial representation of the park. Field surveys will be conducted May through July. The number of visits to each unit each year, and the revisit design across years, will be determined as the protocol is developed. During each visit to a sample unit, a single observer will perform 7-min point counts at each grid point within the first 4 hrs after sunrise. All audio and visual observations will be recorded, and distance to each detected bird will be estimated with a laser rangefinder. Minor modifications may be needed to allow for such an integrated analysis approach using distance-based and other models (e.g., ensuring that counts are long enough to support three or more subsampling intervals for application of removal models). All field personnel will have extensive experience and training in identifying birds of the Northern Great Plains and conducting bird surveys. Standard Operating Procedures will specify requirements for training and certification of technicians at the start of each survey season.

At small NGPN parks, the small number of sampling sites and small number of individuals for species of interest may prevent us from adequately estimating density and occupancy with the approach suitable for larger parks. We will also be examining options for monitoring birds in

small parks that may use different sampling designs or focus on different parameters. If feasible, pilot work will be conducted in 2010 at one or more small parks.

Principal Investigators and NPS Lead:
Dr. Jennifer Blakesley and David Hanni of the Rocky Mountain Bird Observatory (RMBO) are the principal investigators for protocol development during 2008–2009. Through an informal agreement with USGS, the NGPN will cooperate with Dr. Matthias Leu and with RMBO to evaluate strategies for monitoring landbirds in small Network parks. The NGPN has been collaborating closely with NPS Natural Sounds Program, Cornell, and RMBO to assess utility of automated recording units (ARUs) for monitoring birds. The NPS contact person is Marcia Wilson at NGPN, 605-341-2803.

Development Schedule, Budget, and Expected Interim Products:
A final report from 2008–2009 field testing of a draft protocol is due May 30, 2010 from RMBO. The Network Data Manager will assist the P.I.'s with development of an Access database that follows the I&M database template. The Network has transferred $45,000 through a CESU agreement to RMBO in FY2008 for this project. In autumn 2009 and winter 2010, Dr. Matthias Leu will work with NGPN staff and RMBO to evaluate options for monitoring birds in small parks, and provide recommendations about protocol development for these parks. Up to $15,000 will be budgeted for this work. A draft NGPN-wide protocol is planned for April 2011, with final approval expected by Nov 2011 and implementation in 2012.

Protocol Development Summary: Prairie Dogs (21 April 2009)

Protocol: Prairie Dog Spatial Distribution and Density [Prairie Dogs]

Parks Where Protocol will be Implemented: SCBL, BADL, DETO, THRO, and WICA

Vital Signs Addressed by Protocol: Prairie Dogs

Justification/Issues Being Addressed:
Black-tailed prairie dogs are an ecologically dominant species that strongly influence grassland biodiversity, vegetative composition and structure, forage availability, and nutrient cycling (Bangert and Slobodchikoff 2006; Desmond et al. 2000; Dinsmore et al. 2003; Hoogland 2006; Lomolino et al. 2004; Miller et al. 2000). The endangered black-footed ferret, present in both WICA and BADL, is dependent upon prairie dogs, as are other species such as the burrowing owl, mountain plover and ferruginous hawks (Miller et al. 2000; USFWS 2000). Prairie dogs may only occupy approximately 2% of their historic range (USFWS 2000; Proctor et al. 2006). Prairie dog management is highly controversial (Hoogland 2006; Miller et al. 2007), and managers need data on current status, trend and distribution to facilitate and defend management decisions at the five NGPN parks where prairie dogs occur.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

1. For black-tailed prairie dogs, determine summer population density, area, and spatial characteristics of active towns annually at Scotts Bluff NM.
2. Determine total area and spatial characteristics of active prairie dog colonies annually at Wind Cave NP, Badlands NP, Theodore Roosevelt NP, and Devils Tower NM, and integrate spatial data into the NGPN's landcover database.

Basic Approach:
During FY2008, NGPN network staff began a comprehensive review of the literature on prairie dog ecology and monitoring, and drafted a prairie dog ecology conceptual model for the purposes of understanding both external and internal influences upon prairie dog ecosystems and related attributes. Discussions with internal and external NPS staffs indicated that substantive communication with the five parks was required to establish justification for monitoring prairie dogs as well as defining goals and objectives for surveys.

In June 2008, I&M core staff, park resource specialists, and other collaborators met to identify prairie dog ecosystem stressors, prioritize monitoring objectives and discuss opportunities to develop a unified, peer-reviewed protocol. The workshop participants identified spatial area of active prairie dog colonies as the most important parameter to measure at all parks, while SCBL identified prairie dog density as an important indicator, given the small size of its prairie dog populations. Workshop participants recognized the importance of close collaboration in the development of a universal protocol for spatial measurement and suggested that an in-depth investigation into remote sensing of prairie dog colony spatial attributes was warranted. Additional work needs to be done to further quantify and qualify measurement parameters and definition of prairie dog colony attributes. A survey of park resource managers is planned for

early fall 2009 to develop the required information and arrive at a consensus for monitoring SOP's.

NGPN's lead investigator traveled to SCBL in June 2008 and assisted the HTLN staff with monitoring one colony of prairie dogs. The travel afforded greater familiarity with the HTLN monitoring protocol and operating procedures. The 2008 field data are being shared, and data analysis and study is ongoing at both networks. A subsequent trip to SCBL was conducted by NGPN staff in September 2008 to gather additional spatial mapping data of SCBL's primary prairie dog colony predicated on an experimental definition of a prairie dog colony's perimeter. DETO's prairie dog colony was also GPS mapped utilizing the experimental definition and data analysis will be conducted during the summer and fall 2009. Lead investigators will also assist with the HTLN prairie dog monitoring protocol in June 2009.

Prairie dogs have been monitored at SCBL since 1995, and in 2010, the NGPN will assume this responsibility. Leading up to that transition, NGPN and HTLN will continue to discuss potential improvements to the HTLN protocol, given that recent studies (Magle et al. 2007; Facka et al. 2008; Sidle et al. 2002; Assal and Lockwood 2007) have questioned the utility of the density-estimation method prescribed by the Plumb et al. (2001) protocol used at SCBL. Beginning in early June 2008, the Kansas State University Cooperative Wildlife Research Unit, with Dr. Jack Cully as the PI, began a 3 year prairie dog population monitoring study that includes a sampling site at SCBL. The research consists of a sub-sampling, Mark/Recapture exercise intended to last through three seasons at Scottsbluff National Monument, Old Bents Fort, Sand Creek Massacre Historic Site and Fort Larned National Historic Site. Based upon the research study plan, Mark-Recapture data collected at SCBL will most likely be pooled with data collected at the other three NPS study sites; the data analyzed and a density estimate for each parks' prairie dog colony projected utilizing Program Mark software developed by White et al. NGPN continues to explore opportunities to conduct its own Mark/Resight study of prairie dogs in up to three parks in the Network (SCBL, DETO and BADL in further data comparison efforts to develop statistically valid density/ha estimates of prairie dogs at SCBL.

Badlands National Park, Wind Cave National Park, Theodore Roosevelt National Park and Devils Tower National Monument annually or bi-annually map the spatial extent of active prairie dog colonies in those respective parks. NGPN has begun to accumulate historical GPS mapping data from each of the parks and plans to begin a comparative pilot study during the winter of 2009–2010 intended to provide ground truthing of spatial occupancy analysis of aerial imagery utilizing Erdas Imagine Image estraction software. The results of this exercise should provide quantifiable information relevant to the accuracy and utility of estimating spatial occupancy of prairie dogs with aerial imagery.

Given I&M budget limitations and the ongoing need for spatial occupancy data, managers at BADL, THRO, and WICA, will continue to conduct on-the-ground monitoring. However, the parks and I&M core staff will continue to explore the feasibility of a protocol that combines mapping of active towns from remote / aerial imagery, with ground validation by park staff. NGPN and THRO staff have tentatively agreed to explore standardized SOPs for data collection and analysis of aerial imagery data utilizing annual USDA NAIP imagery. There seems to be universal understanding between NGPN and staff at the parks that NGPN Staff and seasonals can

be available on a limited basis to collect spatial GPS mapping data at the respective parks in a contingency to further accumulate supporting GIS data for the image extraction spatial estimation methodology.

Staff at THRO plan to work with I&M to develop the aerial image extraction and spatial measurement GIS approach over the next 18 months. Over the long term, monitoring would likely incorporate a double sampling approach (e.g., Thompson 2002), with mapping of all colonies via aerial imagery (e.g., NAIP), and random or model-based ground-mapping of selected colonies. Ultimately, the NGPN would hope to develop a formal spatial measurement and mapping protocol applicable to all five parks in the Network.

Principal Investigators and NPS Lead:
The NPS I&M lead is John Wrede at NGPN, 605-341-2805, while Chad Sexton, a GIS specialist at THRO, will be the primary investigator on measuring the spatial occupancy of prairie dogs via remote sensing, pending financial and work direction agreements between NGPN and THRO. Joel Brumm, of the NGPN will collaborate with Sexton and the PI on data analysis, storage and management.

Development Schedule, Budget, and Expected Interim Products:
I&M will work closely with members of the THRO staff to further explore the use of aerial imagery to accurately map prairie dog colonies within THRO, BADL, WICA, DETO and SCBL. Short-term goals through the remainder of 2009 and early 2010 are to accumulate all available prairie dog colony mapping data from WICA, BADL, THRO, DETO and SCBL, catalogue, organize and store the data into a network data base. Additionally, USDA NAIP aerial imagery from the 2002 year forward will be accumulated, clipped and prepared for use in the GIS image extraction process. Plans include utilizing historical GPS mapping data consistently with the aerial imagery to test ground truthing of prairie dog colony spatial images extracted from the NAIP photography. It is likely that extensive computer programming work will need to be conducted to develop algorithms for accurate measurement and analysis of prairie dog spatial occupancy. This initial effort could be completed and summarized by November 2010. Pending the outcome of network budget discussions in September 2009, planning could begin on a double sampling study that could be implemented during the 2010 field season, paralleling the KSU study; with data analysis and conclusions published by January 2011. In conjunction with the annual prairie dog survey at SCBL, it may be prudent to design and develop a double sampling mark/re-sight study, utilizing the Magle et al. (2007) methodology, to test the accuracy of the prairie dog density estimates derived from the protocol presently employed at SCBL as well as those produced by the KSU investigation that is presently ongoing. This may be necessary to address the issues and questions raised in the Magle et al. (2007) and Facka et al. (2008) studies. It is not likely that data from those efforts could be effectively analyzed and published before April 2012. Hence, the development of the protocol will likely stretch well into late 2011, and the first draft is expected by March 2012. Implementation will likely occur in June 2013. It is estimated that the Network would have to budget $25,000-$35,000 for the above efforts in FY2010 and FY2011.

Protocol Development Summary: Soundscape (20 April 2009)

Protocol: Soundscape Characteristics [Soundscape]

Parks Where Protocol will be Implemented: All NGPN parks [AGFO, BADL, DETO, FOLA, FOUS, JECA, KNRI, MNRR, MORU, NIOB, SCBL, THRO, WICA]

Vital Signs Addressed by Protocol: Soundscape

Justification/Issues Being Addressed:
Sound levels are important to many parks because of the effects on visitor experience (Gramann 1999). At BADL, 70% of visitors ranked "natural quiet" as very or extremely important (Simmons and Gramann 2001). Yet, air-traffic noise has led two of the Network parks to initiate development of Air Tour Management Plans (MORU and BADL); three other units are candidates for future plans. In addition, MORU has been identified as one of the top five national parks in the nation most threatened by noise pollution (Coalition of NPS Retirees 2008); new railroads are proposed to run next to FOLA and BADL; THRO is concerned about the diminishing sound resources in their wilderness areas; DETO is concerned about the noise generated by Sturgis Rally motorcycle traffic in late summer; and the U.S. Air Force Powder River Training Complex wants to expand its bombing range which will affect the sound environment for several of the Network parks. NPS policy mandates protection and restoration of the natural soundscapes. Noise that adversely affects park resources and visitor experience must be prevented or minimized (NPS 2000: Director's Order 47). Acoustical data can be collected efficiently with automated audio-recording equipment, and can help track changes in specific sounds such as bird and frog calls (e.g., Corn et al. 2000).

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

1. At selected index locations in each park, determine status (at 1–10 year intervals) and trends in acoustical metrics such as natural ambient sound pressure levels, time above ambient level, frequency of intervals with only natural sounds, as well as sound source information (percentage of samples with sounds from anthropogenic and natural sound-source categories).
2. Determine correlations between soundscape changes and changes in visitor numbers, developments, and bird communities.

Basic Approach:
The NPS Natural Sounds Program has developed a draft protocol for acoustical monitoring (NPS 2005) and a draft acoustical sampling and analysis guide (2008). The current protocol involves sampling sound levels and identifying sound sources within representative acoustic zones of a park. The acoustic zones are areas of like vegetation structure, land cover, topography, elevation and climate; the assumption being that similar physical processes occur in areas with similar attributes. Given the expense of the monitoring equipment and the fact these index sites are judged to be representative of the acoustical zones, several index or sentinel sites will be chosen nonprobabilistically in target acoustical zones for each park.

At each index site, automated acoustic instruments will collect the bulk of the data. The sound level measurements will be obtained with equipment that has been calibrated to produce results within one dB of Type 1 instruments. The digital recordings will collect one-second, A-weighted sound levels and one-third octave band measurements from 20 to 20,000 Hz.

Acoustical conditions vary daily and seasonally and this variability must be considered in determining adequate measurement periods. Measurements at a particular site should be sufficient duration to ensure statistical confidence in the data. For sound level measurements a minimum 25-day measurement period has been shown to generally limit measurement uncertainty to less than 3 decibels (NPS 2005).

In addition, knowledge of the source, duration and distribution of sound sources is important in characterizing natural and non-natural acoustic conditions in a park. Thus, during sound-level data collection, periods of observer logging and high-quality digital recordings will be conducted to discern the type, timing, and duration of different sound sources. The digital recordings can also provide an archival record of the biological acoustics of the area.

The recordings will quantify daily and seasonal sound level patterns in standardized frequency bands and identify salient sources of sound, with special focus on biological sounds of special concern and noise sources that require management action.

The frequency with which the acoustical environment will be monitored has yet to be determined. The Natural Sounds Program Center will be developing further sampling plan guidance for acoustical monitoring in the NGPN park units in FY2009.

Principal Investigators and NPS Lead:
Protocol development will be conducted in conjunction with the NPS Natural Sounds Program staff. The Network contact person is Marcia Wilson at 605-341-2803.

Development Schedule, Budget, and Expected Interim Products:
In 2009, a pilot acoustical monitoring project will be initiated in the wilderness at Theodore Roosevelt NP. This pilot work combined with the Natural Sounds Program guidelines will provide the foundation for the Network's draft soundscape protocol. The completion of this draft is scheduled for June 2010.

Protocol Development Summary: Landscape Pattern and Dynamics (25 March 2009)

Protocol: Landscape Pattern and Dynamics [Landscape]

Parks Where Protocol will be Implemented: All NGPN parks [AGFO, BADL, DETO, FOLA, FOUS, JECA, KNRI, MNRR, MORU, NIOB, SCBL, THRO, WICA]

Vital Signs Addressed by Protocol: 1) Land Cover and Use; 2) Fire and Fuel Dynamics; 3) Forest Insects and Diseases; 4) Treatments of Exotic Infestations; 5) Extreme Disturbances

Justification/Issues Being Addressed:
Monitoring of land cover and plant communities complement each other, with compositional and finer scale structural changes being captured via the latter, and larger scale park-wide structural changes captured via this protocol. The type, amount, and arrangement of vegetative structural types are partial indicators of occurrence and abundance of wildlife species that we cannot afford to monitor directly (Vinton and Collins 1997). Fragmentation can widely impact biodiversity and ecosystem function (Saunders et al. 1991), while spatial pattern has fundamental effects on landscape ecology (Turner et al. 2001). To assess changes in vegetation composition and land cover, we need to integrate spatial data collected by others for prescribed and wild fires, other fuels treatments, exotic-plant treatments, and forest insects and diseases. This protocol has relevance to most other protocols. Tracking changes in watershed-level landscape composition may help explain or anticipate water quality changes. Because caves are part of a karst landscape, they may be sensitive to changes in surface use and land cover, especially to changes affecting hydrologic connections. We need to document other infrequent disturbance events (e.g., windstorms), which can shape ecosystems (Friedman and Lee 2002, Parsons et al. 2005).

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:
1. Determine patterns and long-term trends in land cover distribution within and adjacent to NGPN park boundaries.
2. Annually update a spatial database for each park describing characteristics of management activities and natural disturbances (>0.5 ha) within park boundaries known or suspected to influence vegetation structure and composition (e.g., treatment summary and/or spatial/temporal extent of prescribed fires, wild fires, invasive plant control, overstory tree mortality from mountain pine beetles, etc.).

Basic Approach:
This protocol is in initial stages of development. In FY2010, the NGPN will identify a collaborator who will facilitate discussions among NGPN staff and provide landscape-ecology expertise to help the Network determine data needs and to prioritize monitoring objectives. The Network will determine which data will be available through the NPS National I&M Program's efforts to provide a set of core indicators for monitoring landscape dynamics to all I&M Networks, and which data will need to be acquired by the NGPN. The Network will then develop a protocol for acquisition of new data, and summarization, analysis, and reporting of all data needed to meet the objectives for the protocol. This initial needs assessment project will be completed in FY2010, and protocol development will begin late in FY2010.

Principal Investigators and NPS Lead:
We have identified several potential collaborators in consultation with national office staff, but have not yet entered into a formal agreement. The NPS contact person is Joel Brumm at NGPN, 605-341-2804.

Development Schedule, Budget, and Expected Interim Products:
Potential collaborators will be contacted in 2009. We anticipate having a project in place by December 2009, and a draft protocol completed by June 2011. The anticipated budget for the initial needs assessment is $25,000.00.

Literature Cited

Assal, T. J., and J. A. Lockwood. 2007. Utilizing remote sensing and GIS to detect prairie dog colonies. Rangeland Ecology and Management **60**:45–53.

Bangert, R. K., and C. N. Slobodchikoff. 2000. The Gunnison's prairie dog structures a high desert grassland landscape as a keystone engineer. Journal of Arid Environments **46**:357–369.

Bart, J., and S. Earnst. 2002. Double sampling to estimate density and population trends in birds. The Auk **119**:36–45.

Bowles, D. E., M. H. Williams, H. R. Dodd, L. W. Morrison, J. A. Hinsey, C. E. Ciak, G. A. Rowell, M. D. DeBacker, and J. L. Haack. 2008. Monitoring protocol for aquatic invertebrates of small streams in the Heartland Inventory & Monitoring Network. Natural Resource Report NPS/HTLN/NRR—2008/042. National Park Service, Fort Collins, CO.

Breshears, D. D., and F. J. Barnes. 1999. Interrelationships between plant functional types and soil moisture heterogeneity for semiarid landscapes within the grassland/forest continuum: a unified conceptual model. Landscape Ecology **14**:465–478.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Lake, D. L. Borchers, and L. Thomas. 2001. Introduction to distance sampling: estimating abundance of biological populations. Oxford University Press, Oxford.

Choate, J. R., and J. M. Anderson. 1997. Bats of Jewel Cave National Monument, South Dakota. Prairie Naturalist **29**:39–47.

Coalition of National Park Service Retirees. 2008. Peace, quiet and natural sounds. Press release. Online. (http://www.npsretirees.org/pressroom/2008/peace-quiet-and-natural-sounds-america-s-5-best-national-parks-escaping-noise). Accessed 25 July 2008.

Corn, P. S., E. Muths, and W. M. Iko. 2000. A comparison in Colorado of three methods to monitor breeding amphibians. Northwestern Naturalist **81**:22–30.

D'Antonio, C. M., and P. M. Vitousek. 1992. Biological invasions by exotic grasses, the grass-fire cycle, and global change. Annual Review of Ecology and Systematics **23**:63–87.

Davey, C. A., K. T. Redmond, and D. B. Simeral. 2007. Weather and climate inventory, National Park Service, Northern Great Plains Network. Natural Resource Technical Report NPS/NGPN/NRTR—2007/039. National Park Service, Fort Collins, CO.

Desmond, M. J., J. A. Savidge, and K. M. Eskridge. 2000. Correlations between burrowing owl and black-tailed prairie dog declines: A 7-year analysis. Journal of Wildlife Management **64**:1067–1075.

Dinsmore, S. J., G. C. White, and F. L. Knopf. 2003. Annual survival and population estimates of mountain plovers in southern Phillips County, Montana. Ecological Applications **13**:1013–1026.

Facka, A., P. Ford, and G. Roemer. 2008. A novel approach for assessing density and range-wide abundance of prairie dogs. Journal of Mammology **89**:356–364.

Farnsworth, G. L., J. D. Nichols, J. R. Sauer, S. G. Fancy, K. H. Pollock, S. A. Shriner, and T. R. Simons. 2005. Statistical approaches to the analysis of point count data: A little extra information can go a long way. *In* C. J. Ralph and T. D. Rich, editors. Bird Conservation, Implementation, and Integration in the Americas: Proceedings of the Third International Partners in Flight Conference 2002. General Technical Report GTR-PSW-191. U.S. Forest Service.

Flores, D. 1995. History, environment, and future of the Great Plains. Pages 3–9 *in* S. R. Johnson and A. Bouzaher, editors. Conservation of the Great Plains ecosystems: current science, future options. Kluwer Academic Publishers, Boston, MA.

Friedman, J. M., and V. J. Lee. 2002. Extreme floods, channel change, and riparian forests along ephemeral streams. Ecological Monographs **72**:409–425.

Gordon, N. D., T. A. McHahon, and B. L. Finlayson. 1992. Stream hydrology: an introduction for ecologists. John Wiley and Sons. New York, NY.

Gramann, J. 1999. The effects of mechanical noise and natural sound on visitor experiences in units of the National Park System. Social Science Research Review **1**:1–16. National Park Service, Washington, D. C.

Hobbs, R. J., and S. E. Humphries. 1995. An integrated approach to the ecology and management of plant invasions. Conservation Biology **9**:761–770.

Hoogland, J. L. 2006. Conservation of the black-tailed prairie dog: saving North America's western grasslands. Island Press, Washington, D.C.

Lazorchak, J. M., D. J. Klemm, and D. V. Peck. 1998. Environmental monitoring and assessment program-surface waters: field operations and methods for measuring the ecological condition of wadeable streams. U. S. Environmental Protection Agency.

Lenat, D. R. 1984. Agriculture and stream water quality: a biological evaluation of erosion control practices. Environmental Management **8**:333–344.

Lomolino, M. V., and G. A. Smith, 2004. Terrestrial vertebrate communities at black-tailed prairie dog (*Cynomys ludovicianus*) towns. Biological Conservation **115**:89–100.

Longo, P. J., and D. W. Yoskowitz. 2002. Water on the Great Plains: issues and policies. Texas Tech University, Lubbock, TX.

Luckey, R. R., E. D. Gutentag, F. J. Heimes, and J. B. Weeks. 1988. Effects of future ground-water pumpage on the High Plains aquifer in parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming. USGS Professional Paper, 1400-E. Washington, D.C.

Mack, R. N., D. Simberloff, W.M. Lonsdale, H. Evans, M. Clout, and F. Bazzaz. 2000. Biotic invasions: causes, epidemiology, global consequences and control. Issues in Ecology **5**:1–20. Ecological Society of America, Washington, D.C.

MacKenzie, D. I., J. D. Nichols, J. A. Royle, K. H. Pollock, L. L. Bailey, and J. E. Hines. 2006. Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence. Elsevier, Amsterdam.

Magle, S., B. T. McClintock, D. W. Tripp, G. C. White, M. F. Antolin, and K. R. Crooks. 2007. Mark-resight methodology for estimating population densities for prairie dogs. Journal of Wildlife Management **71**:2067–2073.

Miller, B., R. Reading, J. Hoogland, T. Clark, G. Ceballos, R. List, S. Forrest, L. Hanebury, P. Manzano, J. Pacheco, and D. Uresk. 2000. The role of prairie dogs as keystone species: A response to Stapp. Conservation Biology **14**:318–321.

Miller B., R. Reading, D. Biggins, J. Detling, S. Forrest, J. Hoogland, J. Javersak, S. Miller, J. Proctor, J. Truett, and D. Uresk. 2007. Prairie dogs: an ecological review and current biopolitics. Journal of Wildlife Management **71**:2801–2810.

Miller, P. L. 1973. Oxidant-induced community change in a mixed conifer forest. Pages 101–117 *in* J. Naegle, editor. Air pollution damage to vegetation. Advances in Chemistry, Series 122. American Chemical Society, Washington D.C.

Moore, J. C. 1996. Survey of the biota and trophic interactions within Wind Cave and Jewel Cave, South Dakota: final report. University of Northern Colorado, Greeley.
Naiman, R. J., H. Decamps, and M. E. McClain. 2005. Riparia: ecology, conservation, and management of streamside communities. Elsevier: Boston, MA.
Nepstad, J., and J. Pisarowicz. 1989. Wind Cave, South Dakota: temperature and humidity variations. National Speleological Society Bulletin **51**:125–128.
NPS. 2000. Director's Order #47: Soundscape Preservation and Noise Management. Available at: http://www.nps.gov/policy/DOrders/DOrder47.html
NPS. 2005. Acoustics and soundscape studies in national parks (draft). Natural Sounds Program, National Park Service, Fort Collins, CO.
NPS. 2006. Management policies, 2006. National Park Service. Online. (http://www.nps.gov/policy/MP2006.pdf). Accessed 12 September 2007.
NPS. 2008. Acoustical sampling and analysis guide. Online. (http://www1.nrintra.nps.gov/naturalsounds/publications/). Accessed 9 April 2009.
Panjabi, A. 2005. Bird inventories and monitoring on National Park Service units in the Northern Great Plains, 2002-2004: final report. Rocky Mountain Bird Observatory, Brighton, CO.
Parsons, M., C. A. McLoughlin, K. A. Kotschy, K. H. Rogers, and M. W. Rountree. 2005. The effects of extreme floods on the biophysical heterogeneity of river landscapes. Frontiers in Ecology and the Environment **3**:487–494.
Peitz, D. G., and J. T. Cribbs. 2005. Bio-monitoring of water quality using aquatic invertebrates and in-stream habitat and riparian condition assessments: status report for the Niobrara River, Agate Fossil Beds National Monument, Nebraska 1989-2004. National Park Service. Heartland I&M Network and Prairie Cluster Prototype Monitoring Program. Republic, MO. Available from http://science.nature.nps.gov/im/units/htln/aquabugs.cfm.
Peitz, D. G. 2007. Grassland bird monitoring at Agate Fossil Beds National Monument, Nebraska: 2001-2006 Status Report. U.S. Department of Interior, National Park Service, Heartland I&M Network, Republic, MO.
Pohlman, D., and T. Maniero. 2005. Air quality monitoring considerations for the Northern Great Plains Network parks. A report submitted to the Northern Great Plains I&M Program. U.S. Department of Interior, National Park Service, St. Paul, MN.
Plumb, G. E., G. D. Willson, K. Kalin, K. Shinn, and W. M. Rizzo. 2001. Black-tailed prairie dog monitoring protocol for seven prairie parks. U. S. Department of the Interior, U.S. Geological Survey. Prepared for Great Plains Prairie Cluster Long-Term Ecological Monitoring Program, National Park Service.
Proctor, J., B. Haskins, and S. Forrest. 2006. Focal areas for conservation of prairie dogs and the grassland ecosystem. Pages 232–247 *in* J. L. Hoogland, editor. Conservation of the black-tailed prairie dog: saving North America's western grasslands. Island Press, Washington, D.C.
Rejmánek, M., and M. J. Pitcairn. 2002. When is eradication of exotic pest plants a realistic goal? Pages 249–253 *in* C. R. Veitch, and M. N. Clout, editors. Turning the tide: the eradication of invasive species. IUCN SSC Invasive Species Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK.
Rich, T. D., C. J. Beardmore, H. Berlanga, P. J. Blancher, M. S. W. Bradstreet, G. S. Butcher, D. W. Demarest, E. H. Dunn, W. C. Hunter, E. E. Iñigo-Elias, J. A. Kennedy, A. M. Martell, A. O. Panjabi, D. N. Pashley, K. V. Rosenberg, C. M. Rustay, J. S. Wendt, and T. C.

Will. 2004. Partners in Flight North American landbird conservation plan. Cornell Laboratory of Ornithology. Ithaca, NY.
Rust, J. 2006. Establishing baseline data for aquatic resources in national parks of the Northern Great Plains Network. Thesis. South Dakota State University, Brookings, SD.
Saunders, D. A., R. J. Hobbs, and C. R. Margules. 1991. Biological consequences of ecosystem fragmentation: a review. Conservation Biology **5**:1–15.
Scrimgeour, G. J., and S. Kendall. 2003. Effects of livestock grazing on benthic invertebrates from a native grassland ecosystem. Freshwater Biology **48**:347–362.
Sidle, J., D. Johnson, B. Euliss, and M. Tooze. 2002. Monitoring black-tailed prairie dog colonies with high-resolution satellite imagery. Wildlife Society Bulletin **30**:405–411.
Simmons, T., and J. H. Gramann. 2001. Badlands National Park Visitors Study: Summer 2000. Visitors Services Project Report 123. Park Studies Unit, University of Idaho, Moscow. Online. (http://www.psu.uidaho.edu/files/vsp/reports/123_BADL_rept.pdf). Accessed 18 October 2006.
Stevens, D. L., Jr., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association **465**:262–278.
Symstad, A. J. 2004. Interim report: Development of the vegetation component of the National Park Service's Northern Great Plains Inventory and Monitoring Network's "Vital Signs" Monitoring Plan. Report for the Northern Great Plains I&M Program, National Park Service, Keystone, SD. Available at: http://www1.nature.nps.gov/im/units/ngpn/Pages/Monitoring/vegetationSymstad.htm
Thompson, S. 2002. Sampling. 2nd Ed. John Wiley & Sons, Inc., New York.
Toomey, R. S., III. 2006. Geological monitoring of caves and associated landscapes (draft), Mammoth Cave International Center for Science and Learning, Western Kentucky University, Bowling Green.
Trombulak, S. C., and C. A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology **14**:18–30.
Turner, M. G., R. H. Gardner, and R. V. O'Neill. 2001. Landscape ecology in theory and practice: Pattern and process. Springer-Verlag, New York, NY.
USFWS. 2000. 12-month administrative finding, black-tailed prairie dog. 1 February 2000. Summarized in *Federal Register* **65**:5476–5488.
Vinton, M. A., and S. L. Collins. 1997. Landscape gradients and habitat structure in native grasslands of the central Great Plains. Pages 3–19 *in* F. L. Knopf and F. B. Samson, editors. Ecology and Conservation of Great Plains Vertebrates. Springer-Verlag, New York, NY.